IN THE ABSENCE OF THE BLENDING POLICY:
A NOVEL HIGH RATE BIOLOGICAL TREATMENT PROCESS

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ABSTRACT

Infrequent high peak flow events during wet weather can overload wastewater treatment plants. Municipal agencies have often protected their secondary treatment process from washout by bypassing a portion of the influent flow around the process and blending secondary effluent with less treated wastewater (usually primary effluent). In an attempt to rationalize this type of occurrence, EPA proposed a draft Blending Policy in November 2003, which provided conditions under which the blending practice would be allowed. Faced with many negative public comments and resultant opposition in Congress, EPA withdrew the policy in May, 2005. In the absence of the blending policy rule, some municipalities may face future regulatory actions that cause them to eliminate the blending practice and provide for “full” secondary treatment even at peak flows. Wastewater treatment plant expansions to handle these wet weather flow events are typically very expensive, especially given that they are only needed a very small percentage of the time. The Biological Contact process is a novel, cost-effective wet weather treatment technology addressing suspended solids and BOD₅ removal by bioflocculation during wet weather, high flow events. Often, it can be implemented in existing wastewater treatment facilities with the fewest modifications to the current plant configuration. And unlike physical/chemical treatment alternatives, it can achieve secondary treatment requirements for both BOD₅ and SS.

KEYWORDS: Wet Weather Treatment, Peak Flow, Treatment Capacity, Biological Contact Process, Bioflocculation

INTRODUCTION

For the last 50 years, wet weather flows have created widespread difficulties in wastewater collection systems and treatment plants. During wet weather events, wastewater collection systems often deliver high peak sustained flows to wastewater treatment plants. Municipal agencies have often protected their secondary treatment processes from washout by bypassing a portion of the influent flow around the process and blending secondary effluent with less treated wastewater (usually primary effluent). In an attempt to rationalize this type of occurrence, EPA proposed a draft Blending Policy in November 2003, which provided conditions under which the blending practice would be allowed. Faced with many negative public comments and resultant opposition in Congress, EPA withdrew the policy in May, 2005.
In the absence of the blending policy rule, some municipalities may face future regulatory actions that cause them to eliminate the blending practice and provide for “full” secondary treatment even at peak flows through their treatment facilities. The obvious solution to the higher peak flows has been to increase WWTP capacity; however, WWTP expansions require significant capital investment, biological processes have limited peaking capacity, and many facilities are limited by the availability of space. Therefore, municipalities across the US are looking to cost effectively meet permit requirements during wet weather events without spending a large amount of capital.

In the past (and currently), municipalities traditionally increased the capacity of their wastewater treatment facilities to treat peak wet weather storm events by adding additional primary and secondary treatment capacity, by constructing large equalization basins or by adding ballasted sedimentation processes. These types of treatment plant expansions often are very expensive, especially given that they are only needed a small percentage of the time.

This paper describes a novel, cost-effective wet weather treatment technology addressing suspended solids and COD (and BOD$_5$) removal during wet weather, high flow events that can be implemented in existing wastewater treatment facilities often with the fewest modifications to the current plant configuration. And unlike physical/chemical treatment alternatives, it can achieve secondary treatment requirements for both BOD$_5$ and SS.

THE BIOLOGICAL CONTACT PROCESS

The Biological Contact process can be defined as a high rate biological process where mixed liquor or return activated sludge (RAS) is directed from a mainstream activated sludge plant to a small contact chamber, with short hydraulic detention time, where it meets wet weather flows and then passes to a set of secondary clarifiers for final solids-liquid separation. The Biological Contact system’s effluent meets secondary treatment requirements. Figure 1 shows three of the possible variations of the Biological Contact process for wet weather treatment. Mode I involves a diversion line that is activated in wet weather to feed primary effluent directly to a contact tank placed between the existing aeration tanks and secondary clarifiers. Mode II differs from Mode I only in that screened raw wastewater is feed to the contact tank when the diversion line is placed into service during the wet weather event. Modes I and II are usually employed to take advantage of existing secondary clarifier capacity. When secondary clarifier capacity is insufficient and there is no space adjacent to the main process for expansion, Mode III can be used. It involves the construction of new high rate flocculator clarifiers that have demonstrated capability in sustaining high peak surface overflow rates (Parker et al., 1996). As can be inferred from Figure 1C, the process is started up in wet weather by initiation of a diversion from the RAS line of the main stream process in amount proportional to the need to meet the targeted MLSS needs of the Biological Contact process.
Figure 1 – Variations on the Biological Contact Process

(A) Mode I: Primary Effluent Feed to Contact Tank

(B) Mode II: Screened Raw Feed to Contact Tank

(C) Mode III: Separate Wet Weather Clarifiers
The Biological Contact Process is not dissimilar to some of the other variants of the activated sludge process, namely the step feed process, the sludge reaeration process and the contact stabilization process, all of which are shown in Figure 2. Least similar is the sludge reaeration process (Figure 2B), as it typically has two to three hours in its “contact” step. For Biological Contact process Modes I and II, the most similar activated sludge variant is the step feed process, which splits its feeding to all aeration passes in series, but typically increases the fraction of wastewater fed to the last aeration pass during wet weather. For Biological Contact process Mode III, the contact stabilization process is most similar existing activated sludge process variant; here the equivalent of the reaeration tank is the main stream process which serves as the sludge reservoir for the contact tank in the Biological Contact process.

The Biological Contact process “borrows” its mixed liquor from the mainstream activated sludge process, allowing a quick startup during wet weather events. Moreover, no chemical addition is required.

Due to the short retention time in the contact tank during peak wet weather events, it is essential to understand the impact of different operational parameters on the kinetics of particulate and soluble constituent removal. Truly soluble organic constituents can be accurately simulated by either the IWA suite of models (Henze et al., 2000) or the General Model (Barker and Dold, 1997). However, these models are deficient when attempting to describe the rate of particulate removal in contact tanks with low residence times.

Jimenez et al. (2004 and 2005) observed that researchers have overlooked the effect of the kinetics of bioflocculation on the overall particulate substrate removal process in the development of the IWA state-of-the art activated sludge consensus models. These models assume that slowly biodegradable substrates (primarily particulate and colloidal substrates) are removed from suspension instantaneously by entrapment in the floc (Henze et al., 2000; Insel et al., 2002) and is then either degraded or removed with the excess sludge from the system. One can argue that the developers of the IWA activated sludge models did not focus on bioflocculation due to the very high hydraulic retention times (HRT) attendant with the design of nitrification and biological nutrient removal systems they emphasized in their modeling. However, the same assumption has carried over to design of systems with low hydraulic residence times. For example, Henze et al. (2002) state that the particles of the wastewater are quickly absorbed to the activated sludge flocs so that a model description of this adsorption will not be necessary even in a high rate BOD removing activated sludge process preceding a second stage nitrification step.
Figure 2 - Activated Sludge Process Variants Closely Related to the Biological Contact Process

(A) Step Feed Process

(B) Sludge Reaeration Process

(C) Contact Stabilization Process
The Biological Contact process relies on the removal of particulate substrate (suspended particles and colloidal material) by biological flocculation in the contact chamber. Jimenez et al. (2005) presented a first-order kinetic expression to describe the removal of particulate material in the aeration basin of the activated sludge plant. This expression is used to simulate the removal of particulates by biological flocculation at different operating conditions in the contact basin. Therefore, it is the principal kinetic expression used to size the Biological Contact process. The rate expression is as follows:

\[ r_{\text{flocculation}} = -k \cdot (C - a) \cdot X \]  

(1)

Where:

- \( r \): flocculation rate (mg/L.min)
- \( k \): first-order flocculation constant (L/mg.min)
- \( C \): concentration of particles in the supernatant after 30 minutes of settling (mg/L)
- \( a \): residual concentration of particles (mg/L)
- \( X \): MLSS concentration in the aeration chamber (mg/L)

**Approach for Sizing the Biological Contact Process**

During the incidence of peak wet weather flows, the retention time in the Biological Contact process is typically less than one hour and usually on the order of 30 minutes or less. In order to get the highest possible throughput rates through the secondary clarifiers in the process, mixed liquor levels are purposely reduced. However, the lower MLSS levels cause bioflocculation rates to slow down in the contact tank. A balanced design considers both the clarifier operating conditions and the contact tank operating conditions. To produce an optimized design, site specific kinetic parameters are required.

On-site jar test experiments must be performed to determine the kinetics of bioflocculation, the flocculation potential of the mixed liquor and the effect of mixed liquor concentration and contact time on the removal of particulate substrate. Figure 3 shows a jar test in use during testing.
Figures 4 through 6 show the results of a jar test experiments on the removal, by bioflocculation, of supernatant suspended solids (SSS), colloidal COD (CCOD) and particulate BOD$_5$ (PBOD$_5$), respectively, at a mixed liquor concentration of approximately 2,000 mg/L for treatment plant A. These figures also show that Equation 1, used in a mass balance on unflocculated influent particles in a batch or plug flow reactor, fits very well the experimental data obtained in the jar test experiments. Similar results were obtained at the different influent-to-mixed liquor ratios. The kinetic coefficients are summarized in Table 1.

Figure 4 – Plant A Jar Test Results on Supernatant TSS – MLSS = 2,000 mg/L

![Figure 4 - Plant A Jar Test Results on Supernatant TSS](image-url)
Figure 5 – Plant A Jar Test Results on Supernatant CCOD – MLSS = 2,000 mg/L

![Graph of supernatant CCOD vs. contact time]

Figure 6 – Plant A Jar Test Results on Supernatant PBOD5 – MLSS = 2,000 mg/L

![Graph of supernatant PBOD5 vs. contact time]

Table 1 – Summary of Bioflocculation Kinetic Coefficients determined for Plant A

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Residual Concentration [mg/L]</th>
<th>First-Order k [L/min mg]</th>
</tr>
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<tbody>
<tr>
<td>TSS</td>
<td>7</td>
<td>$1.7 \times 10^{-4}$</td>
</tr>
<tr>
<td>Particulate BOD5</td>
<td>4</td>
<td>$1.3 \times 10^{-4}$</td>
</tr>
<tr>
<td>Colloidal COD</td>
<td>12.5</td>
<td>$6.0 \times 10^{-5}$</td>
</tr>
</tbody>
</table>
Figures 7 through 9 show the predicted effect of mixed liquor concentration and contact time on the removal of TSS, colloidal COD and particulate BOD₅ in a plug flow reactor. As seen in these figures, the MLSS concentration and the residence time in the contact tank of play a major role in the removal of particulate substrate by biological flocculation during high-flow, wet-weather conditions. These figures can be used to approximate the removal of particles in a plug flow reactor at a given mixed liquor concentration and contact time. For instance, if the Biological Contact process is operated at a MLSS concentration of 2,000 mg/L, then about 30 minutes of reaction time is needed for relatively complete removal of particulate substrate by bioflocculation.

**Figure 7 – Effect of MLSS and Contact Time on the Removal of Supernatant Suspended Solids (SSS) for Plant A**

![Graph showing the effect of MLSS and contact time on the removal of supernatant suspended solids for Plant A.](image)

**Figure 8 – Effect of MLSS and Contact Time on the Removal of Colloidal COD (CCOD) for Plant A**

![Graph showing the effect of MLSS and contact time on the removal of colloidal COD for Plant A.](image)
Many operational parameters of the mainstream activated sludge plant will affect the removal of particulate substrate by biological flocculation in the Biological Contact process (Jimenez et al., 2004). Therefore, the design of this high-rate biological process is very case-specific. For example, Figure 10 shows the effect of contact time, for two different activated sludge plants treating different influent wastewaters. As this figure shows, Plant A offers better flocculation potential than Plant B. For instance, if a Biological Contact process were to operate with a MLSS concentration of 2,000 mg/L in Plant A, the contact tank should be sized to maintain a residence time of 25 min for complete removal of TSS. On the other hand, the same contact tank for Plant B should be sized to maintain a residence time of 40 min. Assuming the same influent flow rate for both plants, Plant B would require a contact tank 62.5 percent larger than would Plant A.

Fortunately, as we gain more experience with the process, we can see some trends in the kinetic coefficients that suggest how the mainstream process type impacts bioflocculation kinetics. Nonetheless, it is always preferable to gain site specific information rather than project performance based on the preexisting database.
Comparison of the Biological Contact Process with the Ballasted Sedimentation Process

Ballasted Sedimentation (BS) systems employ physical/chemical treatment and utilize special flocculation and sedimentation systems for the removal of suspended particles in high flow, wet weather events. Normally, the BS system combines grit removal, coagulation, flocculation, static and lamellar clarification, scum removal, and sludge thickening in a single unit. Flocculation and solids contact occur through internal and external sludge recirculation, producing a dense floc with surface overflow rates as high as 60 gpm/sf (Tarallo et al., 2000).

Figure 11 summarizes TSS, COD and BOD₅ removal efficiencies normally achieved by BS systems (CDM, 1999; Tarallo et al., 2000; Brashear et al., 2002). This figure also shows the removal efficiencies of the Biological Contact process during a pilot plant study (Jimenez, 2002). As evident, the TSS removal efficiencies for the two systems are similar. However, the COD and BOD₅ removal efficiencies of the Biological Contact process are 20 to 25 percent higher than those found in BS systems. The main difference in COD and BOD₅ removal efficiencies are attributed to the ability of the Biological Contact process to remove truly soluble organic material in the incoming wastewater. Jimenez (2002) showed that approximately 50 percent of the soluble COD was removed by oxidation at hydraulic retention times of 30 min.
Potential Conversion of Ballasted Sedimentation Processes to Ballasted Biological Contact Processes

One question arises relative to the use of ballasted sedimentation for blending with secondary effluent in separated collection systems: if a municipality has constructed such a system for wet weather treatment and an unfavorable regulatory determination occurs in the future, could they be converted to a ballasted biological process?

Our assumption in this conversion would be that the source of the mixed liquor would be the mainstream activated sludge process which would “loan” a portion of its inventory to the ballasted Biological Contact process during the wet weather event. Therefore, ballast materials would only be added during the storm event rather than continuously circulated through the mainstream activated sludge system. Ballast materials for this type of application have been evaluated by Piirtola et al. (1999a, 1999b, and 2000) in both bench and pilot scale trials. Interestingly, sand which is used in one of the proprietary ballasted sedimentation systems, showed no benefit as a ballasting agent for improving activated sludge settling and compression rates. Of course, biological growth would occur on sand if it were present continuously in the activated sludge process (e.g. the growth of films in expanded bed systems). It was shown that any mineral materials introduced had to have an immediate positive interaction with the activated sludge, to ensure that it would “weight” the sludge. Interaction via flocculation and surface charge interaction was postulated to be the cause of beneficial improvements seen for proprietary talc additives, Clinoptiolite, Montmorillonite and Bentonite. Predicted allowable solids loading rates were shown to increase on secondary clarifiers up to 70 percent, allowing a comparable flow increase (Piirtola et al., 1999a, 1999b, and 2000). From this, one would have to conclude that the ballast addition facilities would have to be changed from sand to one of the
other mineral additives, presumably talc for which there is the most field experience. Moreover, there would be no point in attempting to recover the ballast, as reported recoveries for talc are low (35 to 50 percent with hydrocyclones) and further the overall impact of the recovery process is to break up the activated sludge floc (Clauss et al., 1998).

Table 2 presents the results of calculated solids loading rates for different surface overflow rates through the lamella settler portion of the converted process. It should be noted that the limitation in the lamella settler is not in the clarification zone where the lamellas reside, but in the thickening zone below the lamellas. In that zone, the “plan” area is the only area available for thickening. The highest solids loading rate that would likely be used in designing the thickening zone of conventional secondary clarification is 50 lb/sf.d based on federal and state governmental guidelines (Ekama et al., 1997). Allowing for a 70 percent increase in this value for the effect of ballast addition, one projects a maximum solids loading rate of 85 lb/sf.d. As can be seen from Table 2, this would mean that the lamella clarifier, previously rated at up to 60 gpm/sf as a ballasted sedimentation device, would now be rated at less than 5 percent of its original loading condition. This is obviously not a practical situation.

Table 2 – Surface Overflow Rate and Solids Loading Rate in Conversion of a Ballasted Sedimentation Process to a Ballasted Biological Contact Process

<table>
<thead>
<tr>
<th>Surface Overflow Rate, gpm/sf</th>
<th>Surface Overflow Rate, gpd/sf</th>
<th>Solids Loading Rate a, lb/sf.d</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1440</td>
<td>36</td>
</tr>
<tr>
<td>2</td>
<td>2880</td>
<td>72</td>
</tr>
<tr>
<td>3</td>
<td>4320</td>
<td>108</td>
</tr>
<tr>
<td>4</td>
<td>5760</td>
<td>144</td>
</tr>
<tr>
<td>5</td>
<td>7200</td>
<td>180</td>
</tr>
<tr>
<td>10</td>
<td>14400</td>
<td>360</td>
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<tr>
<td>20</td>
<td>28800</td>
<td>721</td>
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<td>40</td>
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<td>1441</td>
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<td>50</td>
<td>72000</td>
<td>1801</td>
</tr>
<tr>
<td>60</td>
<td>86400</td>
<td>2162</td>
</tr>
</tbody>
</table>

Key assumptions are: The MLSS assumption is 2,000 mg/L and a 50 percent RAS rate; ballast material added is not included in the SLR calculation.

CASE EXAMPLE: ORANGE WATER AND SEWER AUTHORITY (OWASA) - MASON FARM WWTP

OWASA is currently constructing the expansion for the Mason Farm WWTP. This expansion will increase the maximum monthly capacity from 12 to 14.5 mgd and the peak wet weather flow (PWWF) from 26 to 43.5 mgd. During normal operation, the mainstream WWTP will treat wastewater flows up to 32 mgd, which represents a peaking factor of 3.0 times the design average daily flow of 10.5 mgd. However, during peak wet weather events, peaking factors of over 4.0 times the average daily flow have been observed at the Mason Farm WWTP. These
short duration, PWWF events tend to wash the solids out of the aeration basins and overload the settling capacity of the secondary clarifiers and the existing RAS pumps.

Expanding the entire aeration basin, aeration system, and secondary clarifiers to handle these extremely rare events would have been cost prohibitive and impossible due to site constraints. A minor change in the operating scenario and more modest improvements will allow these events to be treated with a reduced additional cost. This PWWF treatment scenario consists of pumping up to 35 percent of the primary effluent directly to cells 5A and 5B at the back end of the aeration basins as a step feed. The primary effluent will then undergo Biological Contact treatment for 10 to 15 minutes before being distributed to the secondary clarifiers. Figure 11 shows BioWin configuration and tank configuration for implementation of the Biological Contact Mode I process at OWASA’s Mason Farm WWTP.

Figure 12 – Biological Contact Treatment Alternative at OWASA Mason Farm WWTP
CONCLUSIONS

The Biological Contact process is a novel, cost-effective wet weather treatment technology addressing TSS and COD (and BOD$_5$) removal during wet weather, high flow events that can be implemented in existing wastewater treatment facilities with relatively few modifications to the current plant configuration, saving much of the capital costs that would occur with a normal capacity expansion.

The process “borrows” its mixed liquor from the mainstream activated sludge process, allowing a quick startup during wet weather events. Moreover, no chemical addition is required.

Optimization of the process among its various modes requires consideration of current facilities as well as wastewater characteristics. On-site jar test experiments allow determination of bioflocculation rate kinetics of bioflocculation and the flocculation potential of the mixed liquor. Process design analyses identify the effect of mixed liquor concentration and contact time on the removal of particulate substrate and allow trade-offs between contact tank sizing and clarifier loading.

REFERENCES


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